1. Wastewater Characteristics and Loading Fundamentals

Needs to Know Criteria
▪ Domestic and industrial wastewater, concerns with wastewater land application of high strength industrial waste
▪ Total, suspended, and dissolved solids
▪ Pathogens
▪ Total coliform bacteria
▪ Parameter used by the Idaho Department of Environmental Quality (DEQ) as an indicator of potential pathogen levels in wastewater effluent
▪ Nitrogen cycle
▪ Hydraulic loading rate
▪ Differences between growing and non-growing season hydraulic loading rates
▪ Nitrogen loading rate
▪ Phosphorus loading rate
▪ COD loading rate
▪ Land Limiting Constituent (LLC)
▪ Wastewater effluent classifications and level of treatment required as defined in the Wastewater-Land Application Permit Rules

To properly operate and maintain a wastewater land application system, it is necessary to understand the basic characteristics of wastewater. Although domestic wastewater is composed of 99.94% water and only 0.06% waste or pollutants, wastewater characteristics are important factors in the design, operation and management of wastewater land application systems.

1.1 Sources of Wastewater

Wastewater is normally classified as coming from *domestic* sources or *industrial* sources:

- The most common source of wastewater is domestic wastewater. Domestic wastewater comes primarily from residences, non-industrial businesses, and institutional sources. Some examples of domestic wastewater are restroom, laundry, and kitchen waste. Domestic wastewater tends to be fairly uniform in composition.
- Industrial wastewater is discharged from industrial facilities and some heavy commercial operations. Industrial wastewater characteristics change with changing production rates and schedules, and it is much more variable than domestic wastewater, possibly containing toxic substances, such as metals. Possible concerns with the land application of high strength industrial wastewater include odor and overloading of the site with constituents (waste elements) in the wastewater stream. These systems typically require additional pretreatment and/or special site management practices to provide good performance.

1.2 Types of Wastewater

Wastewater contains two primary types of waste: *organic* and *inorganic*.

- Organic wastes originate from plant or animal sources and can generally be consumed by bacteria and other organisms. All organic wastes contain carbon.
- Inorganic wastes come from mineral materials, such as sand, salt, iron and calcium, and these wastes are only slightly affected by biological activity.

The source of wastewater influences the amount of organic and inorganic waste in a particular waste stream. For example, wastewater from a meat processing plant will contain high levels of organic waste, while wastewater from a gravel washing operation will contain high levels of inorganic waste.

Two other types of waste are *thermal* and *radioactive* wastes. Thermal power stations and industrial cooling processes may produce wastewater with temperatures exceeding the requirements of the enforcing agency. Hospitals, research labs, and nuclear power plants generate radioactive wastes that are usually controlled at their source.

1.3 Wastewater Physical Characteristics

Physical characteristics of wastewater include color, odor, temperature, and the levels of solids present. Changes in these physical characteristics can indicate unusual *influent* (wastewater entering a treatment system) or operating conditions.

Color

Raw wastewater (prior to any pretreatment and land application) is usually gray in color. Pretreated wastewater will have a color that is indicative of the pretreatment system: wastewater treated in a septic tank will have a gray/black color, but wastewater that has been treated in an aerobic process will have little color. The color of wastewater can also be affected by industrial contributions to the treatment system: color contributed by industry typically is not removed by the pretreatment system.

Odor

Raw wastewater usually produces a musty odor, generally caused by the anaerobic decomposition of organic material. Hydrogen sulfide is frequently the source of a rotten-egg odor in wastewater. Other volatile sulfur-containing compounds, such as *mercaptans*, can also cause noxious odors. These odors are released into the air when wastewater is aerated and sometimes when the wastewater is discharged to a land application site.

Unusual odors, such as petroleum or solvent odors, may indicate abnormal industrial discharges.

Temperature

Wastewater is generally somewhat warmer than tap water. A significant increase in wastewater temperature over a short period of time may indicate an unusual industrial discharge, while a significant decrease may indicate an influx of storm water into the treatment system.

Temperature is an important factor in *microbial* activity. Up to a point, an increase in wastewater temperature will increase microbial activity. However, when wastewater reaches high temperatures, microbial activity will be inhibited.

During land application of wastewater, high wastewater temperatures can also adversely impact cover crops.

Solids

One of the primary functions of a wastewater pretreatment system is the removal of solids from wastewater. If the level of solids is not significantly reduced by pretreatment, these materials can reduce the effectiveness of disinfection systems and clog land application equipment.

Determination of the forms and concentrations of solids present in wastewater can provide an operator with useful data for the control of treatment processes. Solids are divided into several different fractions: *total solids, dissolved solids* and *suspended solids*, as shown in Figure 1-1.

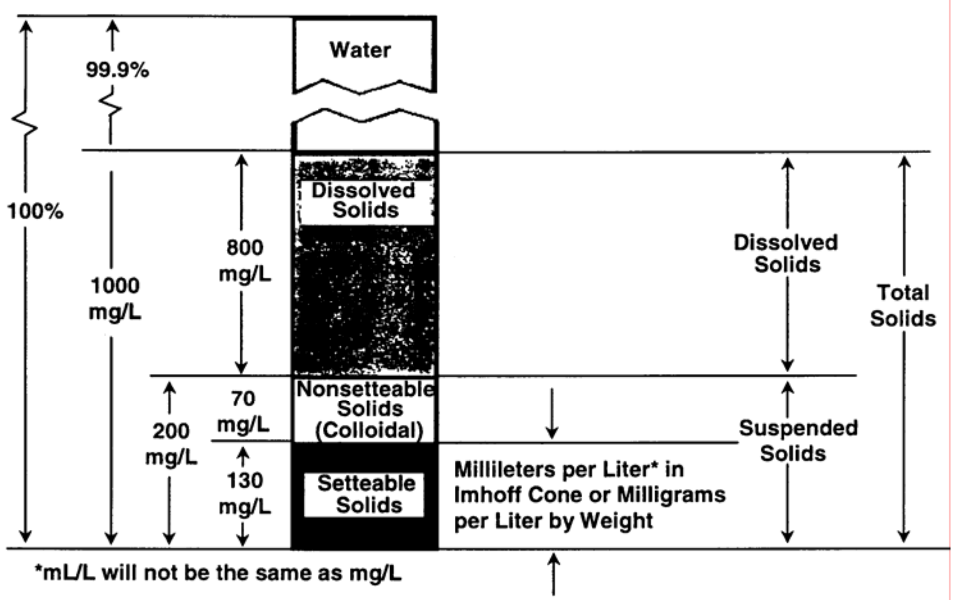

Figure 1-1. Typical composition of solids in raw wastewater (EPA 2004).

Total Solids (Residue)

Total solids are the amount of material that remains after the wastewater is evaporated at a temperature of $103^{o}C$ to $105^{o}C$. Imagine that an operator collects a one-liter sample of influent that is heated to evaporate all of the water. The remaining solids weigh 1,000 milligrams. Thus, the total solids (*residue*) concentration in the sample is 1,000 milligrams per liter (mg/L). This concentration includes both dissolved and suspended solids.

Dissolved Solids

Dissolved solids, also called *filterable residue*, are those solids that will pass through a very fine (0.45-micrometer [μm]) membrane filter. Again, imagine an operator collects a one-liter sample of raw wastewater and filters it through a very fine mesh filter, such as a fiberglass filter. The dissolved solids will pass through with the water, and the operator can now evaporate the water and weigh the residue to determine the weight of dissolved solids. In Figure 1-1 the amount of dissolved solids is 800 mg/L.

Removal of dissolved inorganic solids from wastewater is difficult to achieve in standard municipal wastewater treatment systems, so concerns with land applying wastewaters that have high concentrations of dissolved solids include: 1) the potential for increased levels of dissolved solids in ground water and 2) the potential for adversely affecting soil properties that are important to land application operations.

Suspended Solids

Suspended solids, also called *nonfilterable residue*, are the portion of total solids retained by filtration. Suspended solids (SS) can be removed from a wastewater stream by physical, biological, and/or chemical processes. These solids are classified as either *setteable* or *nonsettleable* (*colloidal*), depending upon their size, shape, and density (weight per unit volume). Larger particles tend to settle more rapidly than smaller particles.

The amount of settleable solids in the raw wastewater is an important factor for the design of settling basins, sludge pumps, and sludge handling facilities. Also, measuring the amount of settleable solids entering and leaving a treatment unit allows the operator to calculate the efficiency of the treatment unit for removing the settleable solids. When a device called an *Imhoff cone* is used to measure settleable solids, the results are expressed in milliliters per liter (ml/L).

An operator can calculate the weight of nonsettleable solids using Equation 1-1.

Weight of nonsettleable Solids	=	Weight of Total Solids	-	Weight of Dissolved Solids	-	Weight of Settleable Solids

Equation 1-1. Calculation for weight of nonsettleable solids.

In Figure 1-1, the nonsettleable solids concentration is shown as 70 mg/L.

Concerns with the land application of wastewaters with high concentrations of suspended solids include: 1) the potential for reducing the infiltration capacity of the soil (clogging the soil) and 2) the potential for damaging the cover crop.

1.4 Other Important Wastewater Characteristics

Other important wastewater characteristics that need to be addressed include pathogenic organisms, biochemical oxygen demand, dissolved oxygen, nutrients, metals, persistent organic chemicals, pH, and salts.

Pathogenic Organisms

Raw domestic wastewater contains many billions of microorganisms per gallon. Most of these are not harmful to humans, and some of them are helpful in wastewater treatment processes. However, humans and warm-blooded animals with diseases caused by bacteria or viruses may discharge some of these harmful organisms in their body wastes (fecal wastes), and many serious outbreaks of communicable diseases have been traced to direct contamination of drinking water or food supplies by the body wastes from a human disease carrier.

Disease-causing microorganisms are called *pathogens*, and they include bacteria, viruses, fungi, and and protozoa. Some known examples of diseases that may be spread through wastewater discharges are typhoid, cholera, shigellosis, dysentery, polio, and hepatitis.

Fortunately, the bacteria that grow in the intestinal tract of diseased humans and warm-blooded animals are not likely to find the environment in a wastewater treatment system favorable for their growth and reproduction. Although many pathogenic organisms are killed (called *natural die-off*) during the normal treatment processes, sufficient numbers can remain in the *effluent* (wastewater leaving the treatment system) to cause a threat to any downstream use involving human contact if adequate disinfection is not accomplished in the treatment process.

Identification of Pathogens

It is impractical to test wastewater for all pathogens. Instead, indicator bacteria organisms are commonly used to indicate fecal contamination and the possible presence of pathogens. One commonly used indicator is *total coliform bacteria*, a group of bacteria that are easily identified through laboratory tests. Total coliform bacteria are always present in the digestive systems of humans and warm-blooded animals. If there is a large concentration of coliform bacteria present in wastewater, the potential for the presence of pathogens is high. The Idaho Department of Environmental Quality (DEQ) uses total coliform bacteria as the indicator of potential pathogen levels in land-applied wastewater.

Removal of Pathogens

Wastewater treatment processes remove pathogenic organisms in several ways: physical removal through filtration and sedimentation, natural die-off of organisms because of unfavorable environments, and destruction of organisms by disinfection. Proper disinfection of well-treated wastewater will usually result in essentially a complete kill of the pathogenic organisms. (Disinfection is discussed in more detail in Section 4.)

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is the rate at which organisms use oxygen to stabilize or break down the organic matter in wastewater.

High levels of BOD indicate high levels of organic matter in wastewater. The typical range of BOD in domestic wastewater ranges from 100 to 300 mg/L of BOD.

BOD is measured using a biochemical oxygen demand test, a procedure that measures the amount of oxygen used by a wastewater sample incubated at 20^{o}C for five days. The amount of organic material measured is referred to as BOD_5, referring to the five day length of the test.

Chemical oxygen demand (COD), which can estimate the amount of organic matter in wastewater in only three to four hours, rather than the five days required for the BOD_5 test, can be used as an alternative. The COD test measures the *oxygen equivalent* (in mg/L) of the materials present in the wastewater by oxidizing the wastewater using a strong chemical oxidant. Because the chemical oxidant may react with substances that cannot be broken down by bacteria, COD results are not directly related to BOD_5. However, COD can be used as a means of rapidly estimating the BOD_5 of a sample if BOD_5-to-COD ratios are developed for a particular system.

COD results are typically higher than BOD_5 values, and the ratio between the two will vary from system to system. The BOD_5-to-COD ratio is typically 0.5:1 for raw domestic wastewater and may drop to as low as 0.1:1 for a well-stabilized secondary effluent.

Dissolved Oxygen

Dissolved oxygen (DO) is simply the amount of oxygen dissolved in water and is usually expressed in milligrams per liter (mg/L). Although some microorganisms can survive in *anaerobic* conditions (without oxygen), many of the beneficial microorganisms that stabilize wastewater require *aerobic* conditions (with oxygen).

The amount of oxygen that can be dissolved in water is dependent on temperature—as water temperature increases, dissolved oxygen content decreases and vice versa—and the distribution of oxygen within a lagoon will determine whether the treatment processes involved are aerobic or anaerobic. Maintaining adequate oxygen levels allows the biological process to take place and prevents objectionable odors. Low DO concentrations (less than 1.0 mg/L) can indicate inadequate aeration or an excessive amount of organic material entering the system.

Dissolved oxygen is measured using an oxygen meter and a membrane-covered probe. Probes require careful cleaning and meters must be calibrated routinely to ensure accuracy.

Nutrients

A *nutrient* is any substance that promotes growth and can be taken up by plants or organisms. Wastewater generally contains nutrients, such as nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulfur. In a land application system, wastewater can provide essential nutrients to cover crops. If present at excessive levels, however, some nutrients can become pollutants.

Nitrogen

All lifeforms require nitrogen compounds, such as proteins and nucleic acids, to survive. The largest source ofnitrogen is the air we breath—approximately 78% of air is nitrogen gas (N_2), but most organisms cannot use nitrogen in this form. Plants must receive their nitrogen in a “fixed” form (i.e., nitrate ions (NO_3^-), ammonia (NH_3), and urea [$(NH_2)_2CO$)], and animals receive their nitrogen from plants.

The nitrogen cycle (Figure 1-2) describes the reactions that nitrogen may undergo. Nitrogen starts as a gas (N2) in the atmosphere and is transformed into other forms of nitrogen through nitrogen fixation. Nitrogen is fixed naturally through atmospheric fixation (by lightning) or through biological fixation (by certain microbes living alone in the soil or in a symbiotic relationship with plants in the legume family, such as soybeans and alfalfa, or non legumelagume plants such as alders). Nitrogen is also fixed industrially in the production of fertilizers, which consist of ammonia, urea, and ammonium nitrate (NH4NO3). As plants and animals die, organic forms of nitrogen are returned to the environment, where microorganizms convert the organic nitrogen to ammonia. Much of the ammonia produced by decay and manures are further broken down by nitrifying bacteria into nitrite ions (NO2-) and then into nitrate ions (NO3-) which are available to plants. The nitrogen cycle is completed when denitrifying bacteria convert nitrate ions back into atmospheric nitrogen.

Nitrogen in wastewater occurs in four different forms: organic nitrogen, ammonia (NH3) or ammonium (NH4+), nitrite (NO2-), and nitrate (NO3-). In raw wastewater, organic nitrogen and ammonia levels are generally higher than nitrite and nitrate levels. Organic nitrogen includes such natural materials as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials.

The nitrogen cycle reactions are important because nitrogen is a potentially serious pollutant in wastewater, and its behavior in and benefits to a wastewater land application system are highly dependent on which form the nitrogen is in when applied to the site.

In the nitrate form, nitrogen becomes a highly mobile anion. In this highly mobile form, when the soil nitrogen concentration exceeds permit limits nitrates can be beneficial or cause adverse impacts depending on how the land application site is loaded. If the soil nitrogen concentration exceeds the permit limits for crop uptake, the excess nitrates will be carried below the root zone where it may adversely affect ground water quality. Therefore, the site must be operated to avoid exceeding the permit nitrogen limits.

Total nitrogen is the sum of organic nitrogen, ammonia, nitrite and nitrate. *Total Kjeldahl nitrogen* (TKN) is the sum of organic nitrogen and ammonia. Typical ranges of nitrogen concentrations in raw domestic wastewater are 20 to 85 mg/L for total nitrogen, 8 to 35 mg/L for organic nitrogen, and 12 to 50 mg/L for ammonia. *Plant available nitrogen* (PAN) is nitrogen that exists in forms (NH_4^+ and NO_3^-) that are readily available for uptake by plants.

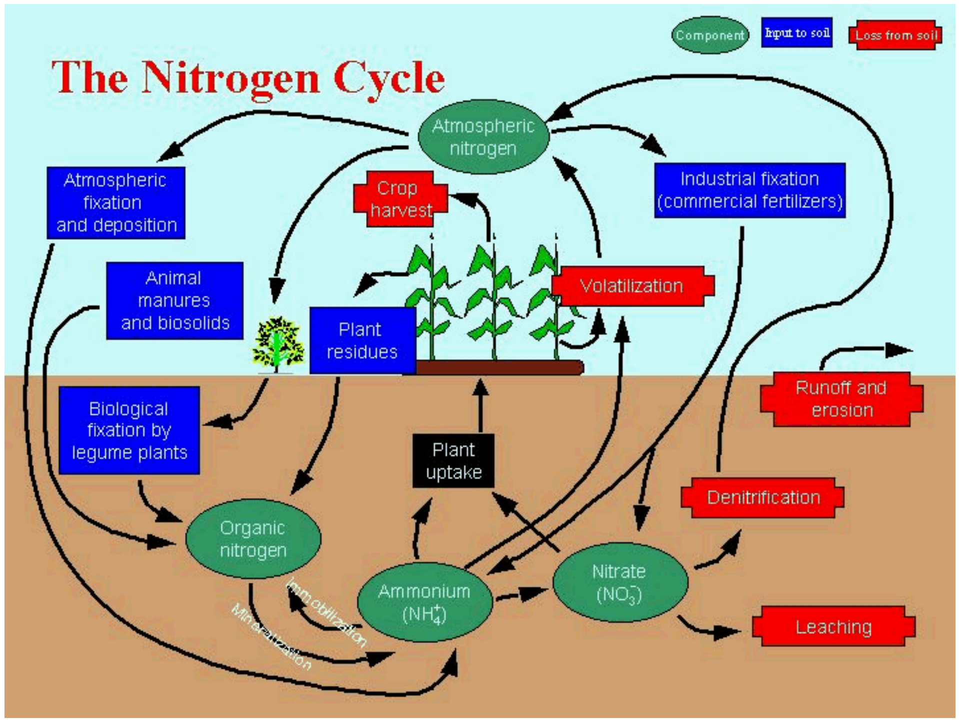

Figure 1-2. The Nitrogen Cycle. (Source: http://msucares.com/crops/soils/images/nitrogen.gif)

Phosphorus

Phosphorus, like nitrogen, occurs in several forms in wastewater and is an essential element for biological growth and reproduction. Phosphorus can be present as orthophosphate, polyphosphate, and organic phosphate. These forms are often measured in combination, as *total phosphate* (total phosphorus) In domestic wastewater, total phosphorus levels generally range from 2 to 20 mg/L, including 1 to 15 mg/L of organic phosphorus and 1 to 15 mg/L of inorganic phosphorus.

Metals

Metals are inorganic chemical elements that are present in varying amounts in most waste streams. Although some metals are essential for proper human and plant nutrition, over time they can accumulate in soils and become toxic to plants, humans, and other animals.

Metals of concern include cadmium, copper, lead, nickel, zinc, selenium, arsenic, mercury, and molybdenum. Cadmium, arsenic, chromium, and mercury are extremely toxic; nickel, molybdenum, and lead are moderately toxic; and copper, manganese, and zinc are relatively low in toxicity.

Concentrations of metals will vary with the type of wastewater. A typical domestic wastewater has low concentrations of metals, but an industrial wastewater may be very high in metal concentration.

The primary concern with using soil to assimilate heavy metals is that these metals are stable and often resist weathering and decomposition. And although plants generally resist the uptake of metals from the soil, their accumulation on plant leaves through irrigation may permit them to enter various food chains, where they become part of the life cycle of soil, plants, animals, and humans, accumulating in animal and human body tissue to toxic levels. This situation is especially critical for humans, who reside at the end of the food chain.

Because of the potential health effects of metals, it is necessary to properly manage wastewater applications sites to minimize the effects of metals on human health and the environment. The paramount questions facing cities or industries contemplating land application of wastes containing heavy metals or toxic substances are: "How many acres of land are required to assimilate this waste?" and "What is the anticipated 'life expectancy' of the site given the accumulation of heavy metals or other toxic substances?"

Persistent Organic Chemicals

Although microorganisms can readily decompose most organic wastes, some organic chemicals are not readily biodegradable and can persist in wastewater and soil for many years. These *persistent organic chemicals* can reach the soil in many ways. They are sometimes a component of pesticides (insecticides and herbicides), or they may be found in the waste stream that is being treated at the land application site. Persistent organic chemicals are also found where old underground storage tanks have leaked petroleum products into the soil.

With a municipal or domestic waste source, persistent organic chemical concentrations are likely to be extremely low, or nonexistent. These chemicals may be present in higher concentrations, however, in an industrial waste source. Like metals, persistent organic chemicals can be toxic to animals and humans.

pH

pH is the measure of the concentration of the hydrogen ions (H^+) in a solution. A pH of 7 is neutral, while a pH reading below 7 indicates *acidic* conditions and a pH reading above 7 indicates *alkaline* (*basic)* conditions. The pH of domestic wastewater typically ranges from 6.5 to 7.5, depending on the pH of potable water in the service system. Significant departures from these values may indicate industrial or other non-domestic discharges.

In land application systems, bacteria may perform wastewater treatment in pretreatment units and in the soil. These bacteria prefer a neutral pH (or 7) for best performance. Any rapid increase or decrease in pH can cause mortality in the bacteria population, resulting in poor treatment.

Note: *Acidity* is the capacity of wastewater to neutralize bases. Wastewater does not have to be strongly acidic (low pH) to have a high acidity. *Alkalinity* is the capacity of wastewater to neutralize acids. Wastewater does not have to be strongly basic (high pH) to have a high alkalinity.

Salts

Chlorides, sulfates, potassium, calcium, sodium and manganese are *soluble salts* (ionic compounds) that are present in wastewater. Some of the salts may be removed during wastewater treatment prior to effluent irrigation. Other salts, such as ferric chloride and alum, are sometimes added to aid in wastewater treatment.

Soluble salts, especially sodium (Na^+), are important constituents of wastewater. When wastewater containing high levels of sodium or other salts is land-applied, there may be some swelling of clay minerals, which can reduce water movement through the soil. This tendency occurs when the ratio of sodium to other *cations* (positively charged particles) is high. This relationship is called the *sodium adsorption ratio* (SAR) of a wastewater sample or soil extract. The SAR of wastewater should be evaluated frequently, especially when irrigating heavy clay soils.

1.5 Municipal Reclaimed Wastewater Effluent Classes

In the State of Idaho, Department of Environmental Quality Wastewater Land Application Permit Rules (IDAPA 58.01.17), various classes (Class A – Class E) of municipal reclaimed wastewater are defined. Requirements for the "direct use" of each class of wastewater are also presented in the rules. Wastewater land application is one type of "direct use." Partial descriptions of the five effluent classes are given below.

- *Class A effluent* is municipal reclaimed wastewater that may be used under particular circumstances for residential irrigation at individual homes (controlled only by the system operator), ground water recharge, surface spreading, seepage ponds, other unlined water features, and other appropriate uses. Class A effluent shall be oxidized, coagulated, clarified, and filtered, or treated by an equivalent process and adequately disinfected. Enhanced filtration approval requirements, nutrient removal requirements, turbidity limits requirements, monitoring requirements, reliability and redundancy requirements, and distribution system requirements also apply.

  Class A treatment systems are required to be pilot tested at full scale prior to sewer hookups, lifting of sanitary restrictions, and start-up. Class A effluent shall be considered adequately disinfected if, at the point of compliance, the median number of total coliform organisms does not exceed two and two-tenths (2.2) per one hundred (100) milliliters, and does not exceed twenty-three (23) per one hundred (100) milliliters in any confirmed sample, as determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

  For ground water recharge, surface spreading, seepage ponds, and other unlined water features, IDAPA 58.01.11, "Ground Water Quality Rule," requirements apply. For Class A effluent, analysis shall be based on daily sampling during periods of use. The point of compliance for Class A effluent for total coliform shall be in the distribution system following final treatment, final storage and disinfection contact time. Residual chlorine at the point of compliance shall be not less than one (1) mg/L free chlorine after a contact time of thirty (30) minutes at peak flow (or an alternate disinfection process

process demonstrated to the satisfaction of DEQ). Class A effluent for residential irrigation should be applied only during periods of non-use. Additional Class A effluent requirements include limits for turbidity, total suspended solids, nitrogen, organics, and pH.

- *Class B effluent* is municipal reclaimed wastewater that may contact any edible portion of raw food crops or is used to irrigate golf courses, parks, playgrounds, schoolyards and other areas where children are more likely to have access or exposure.

  Class B effluent shall be oxidized, coagulated, clarified, filtered, or treated by an equivalent process and adequately disinfected. Class B treatment systems are required to be pilot tested at full scale prior to sewer hookups, lifting of sanitary restrictions, and start-up. Class B effluent shall be considered adequately disinfected if, at the point of compliance, the median number of total coliform organisms does not exceed two and two-tenths (2.2) per one hundred (100) milliliters, and does not exceed twenty-three (23) per one hundred (100) milliliters in any confirmed sample, as determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

  For Class B effluent, analysis shall be based on daily sampling during periods of application. The point of compliance for Class B effluent for total coliform shall be in the distribution system following final treatment, final storage and disinfection contact time. Residual chlorine at the point of compliance shall be not less than one (1) mg/L free chlorine after a contact time of thirty (30) minutes at peak flow. Class B effluent shall be applied only during periods of non-use by the public.

- *Class C effluent* is municipal reclaimed wastewater that will only contact the inedible portion of raw food crops, or that is used to irrigate orchards and vineyards during the fruiting season, if no fruit harvested for raw use comes in contact with the irrigation water or ground or will only contact the inedible portion of raw food crops, or is used to irrigate cemeteries, roadside vegetation, and other areas where individuals have access or exposure. Class C effluent shall be oxidized and adequately disinfected.

  Class C effluent shall be considered adequately disinfected if, at the point of compliance, the median number of total coliform organisms does not exceed twenty-three (23) per one hundred (100) milliliters, and does not exceed two hundred thirty (230) per one hundred (100) milliliters in any confirmed sample as determined from the bacteriological results of the last five (5) days for which analyses have been completed.

  For Class C effluent, analysis shall be based on weekly sampling during periods of application. The point of compliance for Class C effluent for total coliform shall be at the entrance to the distribution system following final treatment and disinfection contact time, but before storage. Class C effluent shall be applied only during periods of non-use by the public.

- *Class D effluent* is municipal reclaimed wastewater that is used to irrigate fodder, seed, or processed food crops and is oxidized and adequately disinfected.

  Class D effluent shall be considered adequately disinfected if, at some location in the treatment process, the median number of total coliform organisms does not exceed two hundred thirty (230) per one hundred (100) milliliters, not to exceed two thousand three hundred (2300) per one hundred (100) milliliters in any confirmed sample, as determined from the bacteriological results of the last three (3) days for which analyses have been completed. For Class D effluent, analysis shall be based on monthly sampling during periods of application. Animals shall not be grazed on land where Class D municipal wastewater is applied, and animals shall not be fed harvested vegetation irrigated in this manner within two (2) weeks of application.

- *Class E effluent* is municipal reclaimed wastewater that is used to irrigate fodder, seed, or processed food crops or forested sites where public access is restricted and the municipal wastewater shall be of at least primary effluent quality. Animals shall not be grazed on land where Class E municipal wastewater is applied, and animals shall not be fed harvested vegetation irrigated in this manner within four (4) weeks of application.

1.6 Hydraulic and Constituent Loading Rates

Three factors must be considered for loading rates: the hydraulic loading rate, the constituent loading rate, and the land limiting constituent; these factors are discussed in the following.

Hydraulic Loading Rate

For wastewater land application systems, the *hydraulic loading rate* is the combination of wastewater and any additional irrigation water applied to a land application site. Example units of measurement include *gallons per acre* and *acre-inches*. (An acre-inch is the volume of water or wastewater covering 1 acre of land to a depth of 1 inch and is equal to 27,154 gallons.)

State of Idaho Department of Environmental Quality wastewater land application permits specify hydraulic loading rate limits for the *growing season* and the *non-growing season*. A site's growing season is identified by climatic conditions, which vary throughout the state. Typical growing season dates are April 1 through October 31, and typical non-growing season dates are November 1 through March 31.

The growing season hydraulic loading rate limit is typically specified to be no greater than the *Irrigation Water Requirement* (IWR) of the crop (the moisture requirement of the crop). (The calculation methodology for the IWR is covered in Section 10, *Calculations*.)

For those permits allowing non-growing season wastewater land application, the non-growing season (NGS) hydraulic loading rate is generally limited to that given by Equation 1-2.

Maximum (NGS) Hydraulic Loading Rate	=	Available Water-Holding Capacity of the Soil	+	Evapotranspiration in the NGS	–	Average Precipitation in the NGS

Equation 1-2. Calculation of maximum hydraulic loading rate.

An important objective of a wastewater land application system is to assimilate and treat all applied wastewater, supplemental irrigation water, and expected precipitation. The primary concerns with hydraulic overloading at a land application site are leaching of wastewater elements into the ground water, runoff, and soil erosion which can cause contamination of surface waters. An additional concern is a reduction in biological activity in the soil. To prevent runoff from a land application site, hydraulic loading rates should not exceed the soil infiltration rate. For sites that land-apply during the non-growing season, it is particularly critical in winter months to not exceedthe soil infiltration rate to prevent leaching of wastewater below the root zone and to prevent runoff from the site that may be accelerated due to freezing conditions and ice buildup. During the growing season, the health of the cover crop may be adversely affected with either excessively high or low hydraulic loading rates. Hydraulic loading rates above permit rates must be avoided at all cost to prevent leaching of wastewater to ground water and runoff. Contact the DEQ regional office in your area if hydraulic loadings above permit limits are needed to avoid lagoon over topping or other emergencies.

Constituent Loading Rates

The loading rates of constituents or waste elements are important operating parameters at a wastewater land application site. Constituents that are typically evaluated include: nitrogen, phosphorus, and chemical oxygen demand (COD). The constituent loading rates for nitrogen, phosphorus, and COD are defined as the rate at which these constituents are applied to the site. Loading rates for nitrogen and phosphorus are generally given in pounds per acre per year (lb/ac-yr). The COD loading rate is generally evaluated as pounds per acre per day (lb/ac-day).

Nitrogen

Needs To Know!

The assimilative capacity for nitrogen (N) is an important part of a wastewater land application treatment system. Nitrogen removal can be very efficient in a soil crop system. Efforts must be made, however, to control the leaching and runoff losses of nitrogen compounds. Conditions of rapid water movement beyond the root zone, which can occur with excess water application to soils, can lead to leaching and increased nitrate levels in ground water; approaches to mitigating such effects include the following:

- The basic approach to reduce leaching is to have a crop that will retain or use the nitrogen. This will help prevent excess nitrate accumulation and potential leaching problems and subsequent ground water pollution.
- The basic approach in controlling runoff is to apply runoff control technologies including: hydraulic loading rates not exceeding the soil infiltration rate, uniform sprinkler application, and using runoff control structures, such as berms and ponds.

Phosphorus

Needs To Know!

Phosphorus (P) is a required crop nutrient. It is also a major contributor of pollution to streams, causing algae blooms, low dissolved oxygen, undesirable plant growth, and fish kills. Phosphorus can reach streams by runoff from land application sites or by inflow from aquifer recharge of the stream (ground water/surface water interconnection); mitigation strategies include the following:

- To protect surface waters from the effects of excess phosphorus, surface runoff and deep percolation of phosphorus must be controlled.
- Surface runoff concerns may be prevented or mitigated by applying runoff control technologies.
- Phosphorus impacts to surface water from deep percolation and ground water interconnections may be prevented or mitigated with management of the phosphorus loading rate and management of phosphorus accumulation in the soil.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is a common measure of organic matter in land applied wastewater. Most wastewater land application permits in Idaho have a maximum COD loading rate of 50 lbs/acre-day. Soils are a good medium for the assimilation of the organic matter in wastewater. Excessive COD loadings, however, can create soil clogging, severely limiting the function of a site to treat wastewater. Clogging generally occurs in the top few inches of soil with the continued existence of anaerobic conditions in the soil surface layer. Anaerobic conditions result in a low rate of biological activity and possible sludge accumulation and odor concerns.

Land Limiting Constituent

Wastewater from most domestic and commercial sources contains low concentrations of nitrogen, phosphorus, COD, and other constituents, such as total dissolved solids. For these wastewater streams, the amount of wastewater that can be applied to a treatment site is typically limited by the hydraulic loading rate (*hydraulically limited)*, based on crop water requirements.

With higher strength wastewaters, however, the amount of applied wastewater may be limited by the amount of nitrogen, phosphorus, or COD—for example, in the wastewater stream. This *land limiting constituent* (LLC) then dictates the amount of wastewater that may be land applied. In these cases, sites typically use supplemental irrigation water to insure the crop is receiving adequate moisture for crop health.

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